PS-5.3   Explain how changes in velocity and time affect the acceleration of an object.
       Taxonomy Level: 2.7-B   Understand Conceptual Knowledge

Key Concepts:
Acceleration

Previous/Future knowledge: In 8th grade, students used measurement and time-distance graphs to represent motion of an object in terms of its position, direction, or speed (8-5.1); analyzed the effects of forces (including gravity and friction) on the speed and direction of an object (8-5.3); and analyzed the effect of balanced and unbalanced forces on an object's motion in terms of magnitude and direction (8-5.5). These indicators address how forces influence the motion of an object, and in each case the answer is that a force can cause the speed of an object to increase or decrease or the direction of the object's motion to change. However, 8th grade students do not consider the concept of acceleration. With an understanding of velocity in terms of speed and direction (PS-5.1 and PS-5.2), Physical Science students have the foundation necessary to develop an understanding of the concept of acceleration as the rate of change in the velocity of an object, due to either a change in speed or a change in direction.

It is essential for students to understand
- *Constant Velocity or Zero Acceleration*: The first motion diagram shown below is for an object moving at a constant speed toward the right. The motion diagram might represent the changing position of a car moving at constant speed along a straight highway. Each dot indicates the position of the object at a different time. The dots are separated by equal time intervals. Because the object moves at a constant speed, the displacements from one dot to the next are of equal length. The velocity of the object at each position is represented by an arrow. The velocity arrows are of equal length (the velocity is constant).

       The acceleration in the diagram below is **zero** because the velocity does not change.
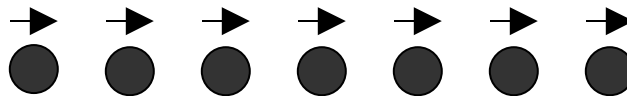
       Below is a data table which shows an example of what instantaneous velocities might be if measured at equal time intervals for **zero acceleration.** Notice the velocity is the same each time.

Time	Instantaneous velocity
Initial time	15 m/s to the right
After one second	15 m/s to the right
After two seconds	15m/s to the right
After three seconds	15m/s to the right
After four seconds	15m/s to the right

- *Constant Positive Acceleration* (speeding up): This motion diagram represents an object that undergoes constant acceleration toward the right in the same direction as the initial velocity. This occurs when the car speeds up to pass another car. Once again the dots represent, schematically, the position of the object at equal time intervals. Because the object accelerates toward the right, its velocity arrows increase in length toward the right as time passes. The distance between adjacent positions increases as the object moves right because the object moves faster as it travels right.

The acceleration in the diagram below is positive because the object is speeding up.

Below is a data table which shows an example of what instantaneous velocities might be if measured at equal time intervals for **positive acceleration.** Notice the velocity is greater each time.

Time	Instantaneous Velocity
Initial time	0 m/s to the right
After one second	5 m/s to the right
After two seconds	10 m/s to the right
After three seconds	15 m/s to the right
After four seconds	20 m/s to the right

Teacher note: Sometimes the direction is defined as the positive direction. (Students do not need to know this)

- *Constant Negative Acceleration* (slowing down): This type of motion occurs when a car slows down. The dots represent schematically the position of the object at equal time intervals. Because the acceleration is opposite the motion, the object's velocity arrows decrease by the same amount from one position to the next. Because the object moves slower as it travels, it covers less distance during each consecutive time interval, so the distance between adjacent positions decreases as the object moves right.

The acceleration in the diagram below is negative because the object is slowing down.

Below is a data table which shows an example of what instantaneous velocities might be if measured at equal time intervals for **negative acceleration.** Notice the velocity is smaller each time.

Time	Instantaneous Velocity
Initial time	20 m/s to the right
After one second	15 m/s to the right
After two seconds	10 m/s to the right
After three seconds	5 m/s to the right
After four seconds	0 m/s to the right

	Forces and Motion
PS-5 The student will demonstrate an understanding of the nature of forces and motion.	

Teacher note: Sometimes the direction is defined as the positive direction or negative direction. (Students do not need to know this)

- *Acceleration due to a change in direction*:

Time	Instantaneous Velocity
Initial time	0 m/s
After one second	5.0 m/s north
After two seconds	5.0 m/s west
After three seconds	5.0 m/s south
After four seconds	5.0 m/s east

  ○ Students should understand that the velocity of the object above is changing because the direction is changing. The speed of the object remains constant.
  - Because the velocity of the object is changing, it is accelerating;
  - Students need only say that the object <u>is</u> accelerating because the direction (and therefore the velocity) of the object is changing. Students need not consider the rate of acceleration for an object that is changing direction.

It is essential for the students to understand
- That *acceleration* is a measure of the <u>change</u> in velocity (final velocity - initial velocity) per unit of time. When the velocity of an object is changing, it is accelerating.
- That if the object slows down, the change in velocity (v_f- v_i) is negative so the acceleration is negative and conversely when the object is speeding up the acceleration is positive.
- That both the change in velocity and the time it takes for that change to occur are important when considering the acceleration of an object.
  o When comparing the acceleration of two objects that have the same change in velocity, the one that undergoes the change in the least amount of time has the greatest acceleration.
  o When comparing the acceleration of two objects that accelerate over the same interval of time, the one that undergoes the greatest change in velocity accelerates the most.
- That acceleration is always measured in velocity (distance/time) units divided by time units. Example: Acceleration is change in velocity divided by time. The unit for velocity is m/s and the unit for time is second so the unit for acceleration is m/s/s or m/s^2. This is derived from velocity (m/s) divided by time (s).
- Students should understand acceleration units conceptually as "change in velocity over time" rather than "distance over time squared".
  o The most common acceleration units in the metric system are m/s/s or m/s^2.
  o The time units may be different in the velocity part of the equation and denominator such as km/hr per second.
- The velocity of an object can change two ways, so an object can accelerate in two ways:
  ○ The speed can increase or decrease
  ○ The direction can change.

It is not essential for students to solve mathematical problems involving acceleration for an object that is changing direction.

Forces and Motion
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Assessment Guidelines:
The objective of this indicator is to _explain_ how changes in velocity or time affect the acceleration of an object, therefore, the primary focus of assessment should be to a construct a cause and effect model showing how changes in speed, direction, or time affect the acceleration of an object.

In addition to _explain_, assessments may require that students:
- _Exemplify_ how each variable influences the acceleration of an object;
- _Compare_ negative and positive acceleration;
- _Summarize_ the effect of each variable on the acceleration of an object;
- _Infer_ from experimental data the relative acceleration (greater rate of acceleration vs. lesser rate of acceleration) of two objects;
- _Interpret_ accelerated motion on a motion diagram;
- _Illustrate_ accelerated motion using motion diagrams